AN INVESTIGATION OF SURFACE CURRENTS AND INTERNAL WAVES OVER THE INNER AND MID SHELF DURING THE DUCK94 EXPERIMENT

Hans C. Graber
RSMAS - Applied Marine Physics
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098
phone: (305) 361-4935, fax: (305) 361-4701, e-mail: hgraber@rsmas.miami.edu
Lynn K. Shay
RSMAS - Meteorology and Physical Oceanography
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098
phone: (305) 361-4075, fax: (305) 361-4696, e-mail: lshay@rsmas.miami.edu
Brian K. Haus
RSMAS - Applied Marine Physics
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098
phone: (305) 361-4935, fax: (305) 361-4701, e-mail: bhaus@rsmas.miami.edu
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LONG-TERM GOAL

To understand the dynamics and temporal and spatial variability of the circulation over the inner to mid-shelf region and to examine which mechanisms and interactions are responsible for observed surface flow features? In addition, we seek to understand to the capability of this remote sensing technique for high-resolution wind and wave measurements in coastal regions.

SCIENTIFIC OBJECTIVES

In this study we seek to establish a better understanding of the dynamics and variability of the circulation over the inner and mid shelf. Using a combination of spatial and temporal high-resolution remotely sensed surface vector current maps and in-situ current and hydrographic observation we like to determine the plausible mechanisms and interactions which drive the circulation over the inner and mid shelf. The high-resolution HF Doppler radar measurements will make it feasible to evaluate the alongshore variability of the cross-shelf transport, which is critical in assessing beach erosion and sediment transport. In addition, wind and waves are also crucial forcing function over the shelf. By estimating winds and waves from the radar measurements, we expect to investigate the ocean current response of the inner-shelf waters with respect to wind and wave effects, including the transfer of wave momentum to the mean flow. Finally, the unique data set obtained in this way will let us resolve the surface and subsurface internal wave response (from f to the Nyquist frequency of 1.5 cph) over the shelf region including barotropic and baroclinic tidal effects.

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APPROACH

During the second phase (October 1994) of the DUCK94 experiment we deployed a dual-frequency, linear-phased array HF Doppler radar to measure surface currents, surface gravity waves and wind speed and direction at high spatial and temporal resolution and over a large domain between the US Army Field Research Facility (FRF) and Corolla, NC. The remotely-sensed surface vector currents provide a synoptic view of the different flow dynamics in the coastal ocean. Using improved algorithms, which we developed based on previous theory and data sets, we will also extract wind and wave information from the Doppler spectra.

WORK COMPLETED

Completed works include:

1. All surface vector currents have been processed and quality controlled. From this data set we computed tidal currents, mean (low-pass), band-pass and high-pass current fields;
2. All Doppler spectra for the month long measurement period have been processed and information of the energy in the first and second-order peaks have been extracted for computations of wave heights;
3. A data report describing the OSCR measurements has been distributed to all DUCK94 investigators;
4. A detailed comparison has been completed between the OSCR vector currents and the current meters at the 20 and 25-meter CoOP moorings from S. Lentz (WHOI);
5. The Doppler spectra were used to evaluate different wave height algorithms and make improvements on the modified Barrick (1977) algorithm (S. Heron, 1996, Honors Thesis);
6. Two periods have been analyzed when salinity measurements at the two WHOI moorings showed evidence of the presence of a coastal buoyant jet;
7. Two time periods were selected to analyze in detail the characteristics of the coastal buoyant jet;
8. Bragg peak ratio was used to extract high-resolution wind directions for several time periods; and
9. Radar-derived wave height maps were validated and compared with in-situ wave buoy (from R. Jensen, CERC) and pressure gauges along offshore transect (from T. Herbers, NPS).

RESULTS

Comparisons of the HF-derived surface currents to the subsurface currents from two Vector Measuring Current Meters at 4 and 6 m indicated biases of 2 to 6 cm/s, slopes of O(1), and rms differences of 7 to 9 cm/s (Shay et al. 1997). These rms differences approach the uncertainties in the HF-radar of 5 cm/s and the VMCM of 2 to 3 cm/s. Tidal forcing consisted of diurnal (K_1) and semidiurnal (M_2) tidal constituents where the surface and subsurface (4 m) speeds were 3 and 8 cm/s, and 2 and 7 cm/s, respectively. The semidiurnal component was barotropic with M_2 amplitudes of about 8 to 10 cm/s in the far-field as it propagated in a cross-shelf direction (Cook and Shay, 1998).

The temporal and spatial measurements of the detided surface current fields can provide critical quantitative information on characterizing a buoyant coastal jet in terms of width, offshore distance, velocity and spatial variability. The results show that the detided, alongshore velocity field can clearly demarcate the near- and offshore boundaries of the coastal jet. Furthermore, a widening of the jet towards the south is visible that could be caused by bathymetric features there.

The DUCK94 HF radar data provided a unique opportunity to improve and validate the system's capability to measure significant wave height. Heron and Heron (1997) evaluated several existing algorithms based on simple power-law relations involving the ratio of the integrated weighted second-order radar cross-section to the first-order radar cross-section. They found that the half-power law, $H_{rms} = \alpha \lambda R^{1/2}$, is robust for rms wave heights as low as 20 cm. Here $\alpha = 1/3$ is an empirical constant and R is a weighted ratio of the integrals as defined in Barrick (1977). Heron (1996) has examined in detail the application of these three different power law relations for estimating wave heights with HF radar backscatter data acquired during DUCK94. He found that a modified version of Barrick's (1977) algorithm provided the most accurate wave height estimates with a rms error of only 14 cm for wave heights ranging from 50 cm to 4 m. Sequences of hourly averaged wave height maps derived from three 20-minute OSCR Doppler spectra delineate the spatial evolution of the storm-generated waves as they approach the shore. As the storm strengthened the wave heights appear to be uniform in the alongshore direction. Whereas at the peak of the storm the influence of the bottom through shoaling and depth refraction is quite apparent displaying spatially variable wave heights over the inner shelf (water depth $\leq$ 25 m) (Graber and Heron, 1997).

We have also used the DUCK94 data set to estimate the wind direction form the ratio of the powers of the Bragg peaks. The results show the potential for acquiring high-resolution spatial information on the sub-mesoscale variability of the coastal wind field. In particular, the 1 km resolution of wind direction maps can easily detect the location of frontal systems and their subsequent movement onshore or offshore. The agreement with two local wind measurements at the FRF pier and the Inner Shelf wave discus buoy exhibit differences of less than 10 degrees.

IMPACT/APPLICATION

The use of HF radar measurements of high-resolution surface currents, wave height and wind direction estimates provides a new view into the small-scale dynamics affecting coastal and nearshore processes. The combination of in situ measurements with radar observations enhances our understanding of the evolution of the three-dimensional structure of coastal dynamics; in particular the data becomes critical test beds to validate models of coastal circulation and wave height prediction. Ultimately, these results will improve our ability to quantify sediment transport and shore erosion rates and the cross-shelf momentum transport.

TRANSITIONS

Our HF radar measurement capabilities have been used in numerous ONR-funded projects and are rapidly gaining acceptance among the oceanographic community to study coastal dynamics. NRL-Stennis is interested in using such data to validate coastal circulation models, while the US Army Corps of Engineers uses the wave height estimates to improve and validate shallow water wave prediction models.

RELATED PROJECTS

Related projects include:

1. The surface current measurements with OSCR during DUCK94 has helped to support Sarah Rennie (VIMS) and John Largier (SIO) in analyzing the ADCP transect data from the CoOP program;
2. OSCR surface current fields were made available to John Allen (OSU) to examine the impact of assimilating real data in simple coastal circulation models;
3. The study of the coastal buoyant jet has led to a new NRL/ONR funded measurement program on the Chesapeake Bay outfall plume experiment; and
4. OSCR measurements will also be used to provide synoptic measurements of waves and currents during the field program phase of the new ONR-funded Shoaling Waves DRI.

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